

CARBOHYDRATES AND THERE CLASSIFICATION

BCH 202

- Carbohydrates are the most abundant class of biomolecule on earth.
- A carbohydrate is a biological molecule consisting of **carbon (C), hydrogen (H) and oxygen (O) atoms** usually with a hydrogen-oxygen atom ratio of 2:1 as in water.
- They have the empirical formular $(CH_2O)_n$.
- Carbohydrates are **polyhydroxyaldehydes $R-CHO$ of polyhydroxyketones $RC(=O)R'$ or compound that yields such upon hydrolysis.**
- Some carbohydrates also contain nitrogen (i.e. glucoseamine), phosphorous (glu-6-p) and sulphur (i.e. thiosugar).

ROLES OF CARBOHYDRATES IN LIVING ORGANISMS

- Carbohydrates perform numerous functions in living organisms.
- Polysaccharides functions in the storage of energy (e.g. **starch and glycogen**) and as structural component (e.g. **cellulose in plant and chitin in arthropods**).
- The five carbon monosaccharide ribose is an important component of coenzymes (e.g. **ATP, FAD and NAD**). and the backbone of the genetic molecule known as RNA.

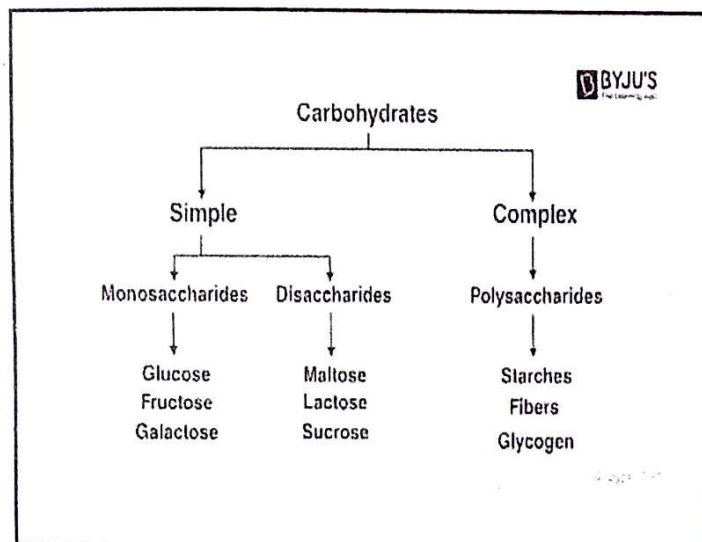
- The related **deoxyribose** is a component of DNA.
- **Saccharides** and their derivatives are important biomolecules that play roles in fertilization, preventing pathogenesis, blood clotting and development.

SOURCES OF CARBOHYDRATES

- ☐ Cereals
- ☐ Wheat
- ☐ Rice
- ☐ Tubers and potatoes
- ☐ Sugarcane
- ☐ Fruits
- ☐ Milk and others

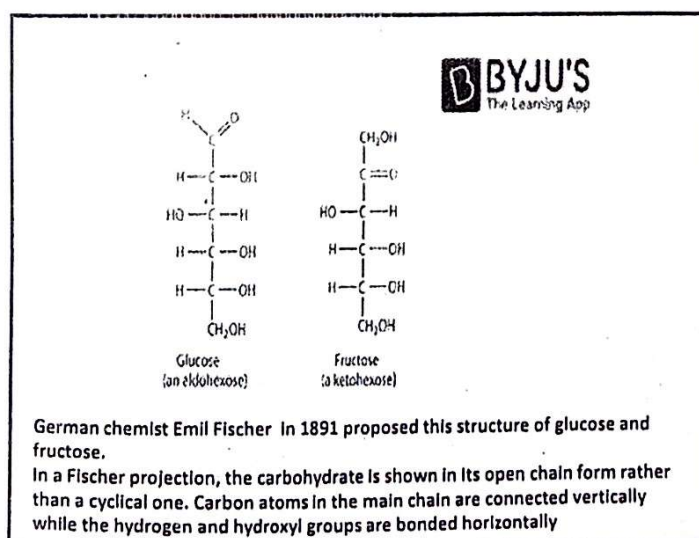
CLASSIFICATION OF CARBOHYDRATES

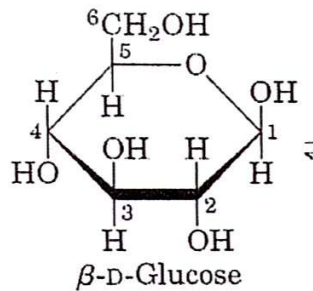
- Carbohydrates are classified into **two** groups namely **simple carbohydrates** and **complex carbohydrates**
 - ☐ Monosaccharides
 - ☐ Oligosaccharides
 - ☐ Polysaccharides



MONOSACCHARIDES

- The simplest of the carbohydrates are the monosaccharide.
- They are either **aldehydes or ketones** with two or more hydroxyl group.
- **Monosaccharide are colourless crystalline** solids that are readily soluble in water but in soluble in non polar solvent.
- Most monosaccharide have a sweet taste.
- Examples of monosaccharide include **glucose, fructose and galactose**.

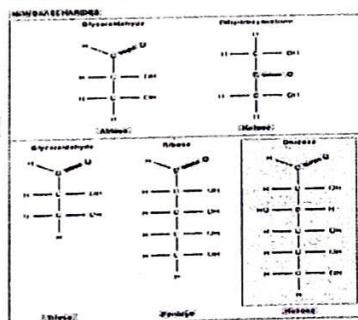




Haworth projection of glucose molecule

- The backbone of common monosaccharide are branched carbon chains in which all the carbon atoms are linked by a single bond.
- In the open chain bond, one of the carbon atom is double bonded to an oxygen atom to form a carbonyl group and each of the either carbon atom has a hydroxyl group.
- If the carbonyl group is at the end of the carbon chain, (i.e. in an aldehyde group) the monosaccharide is an **aldehyde or aldose**.

- On the other hand if the carbonyl group is at any other position the monosaccharide is a **ketone or ketose**.
- The simplest monosaccharide are the two three carbon trioses glyceraldehyde and dihydroxyacetone.

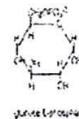


- **Disachharides** such as maltose, lactose and sucrose consist of two monosaccharide joined covalently by an glycosidic bond which is formed when a hydroxyl group of one sugar reacts with the anomeric carbon of another.
- Disaccharides can be **hydrolyzed** to yield their free monosaccharide component by boiling with dilute acid.

DERIVATIVES OF MONOSACCHARIDES

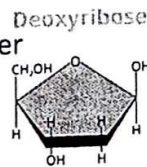
• 1. SUGAR PHOSPHATE

monosaccharides in metabolic pathways are often converted to phosphate esters. The triose phosphates, ribose-5-phosphate and glucose-6-phosphate are example of alcohol phosphate esters.



- 2. **DEOXY SUGAR** here a hydrogen atom replaces one of the hydroxide group in the parent monosaccharide. 2-deoxyribose is an important building block of DNA.

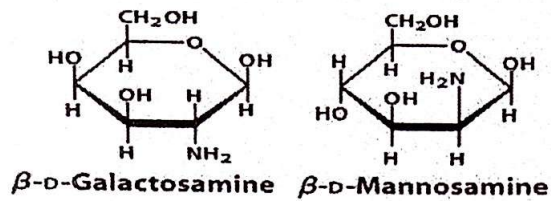
6-deoxy-L-galactose is also another example which is Widely distributed in plants, animals and microorganisms.



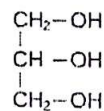
- 3. **AMINO SUGAR** in a number of sugars, amino group replaces one of the hydroxyl group in the parent monosaccharide. Sometimes the amino group is acetylated . Examples are **N-acetyl glucoseamine, N-acetylneuraminic acid and N-acetylgalactoseamine.**

Amino Sugars

Amino sugars



- **SUGAR ALCOHOL:** in a sugar alcohol, the carbonyl oxygen of the parent monosaccharide has been reduced producing polyhydroxyalcohol.
- Examples of sugar alcohols are **glycerol** and **myoinositol** are important components of lipid. Ribitol is a component of **flavin mononucleotide FMN** and **flavin adenine dinucleotide FAD**. In general, sugar alcohols are named by replacing the suffix -ose of the parent monosaccharide with -itol.



- **SUGAR ACIDS** sugar acids are carboxylic acids derived from aldoses either by oxidation of C1 (aldehyde carbon) to yield aldonic acid by oxidation of the highest numbered carbon (the carbon bearing the primary alcohol) to yield alduronic acid.

OLIGOSACCHARIDES

- Oligosaccharides are carbohydrates that contain two or more than two monosaccharides (2-10 units of monosaccharides).
- Oligosaccharides can have many functions including cell recognition and cell binding.
- Most of the few naturally occurring oligosaccharides are found in plants i.e raffinose, galactose.

CLASSIFICATION OF OLIGOSACCHARIDE

- **Trisaccharides:** These types of oligosaccharides are made up of three monosaccharides linked together. Raffinose is an example of a trisaccharide which is composed of glucose, galactose and fructose.
- **Tetrasaccharides:** These are composed of four sugar units. Sesamose, which is made up of four monosaccharides — 2 galactose units, one unit of fructose and one glucose unit.

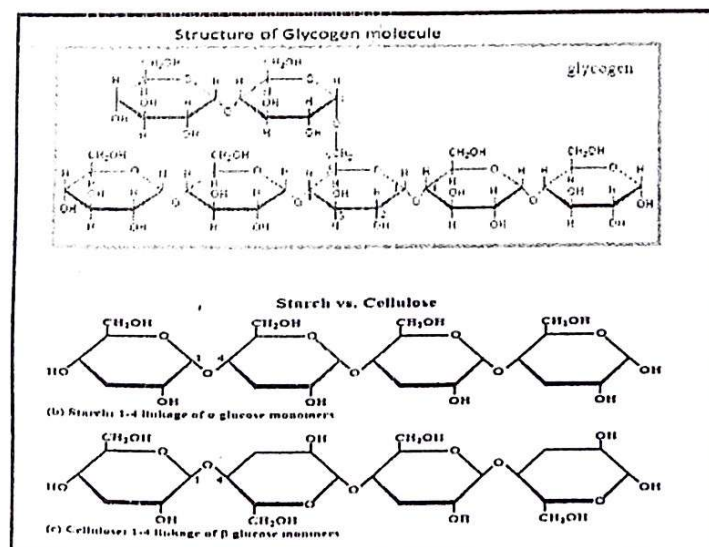
- **Pentasaccharides:** They are composed of five monosaccharides. Examples include verbascose, which is composed of three units of galactose, one unit of fructose and one unit of glucose.

POLYSACCHARIDE

- Most carbohydrates found in nature are in the form of **polysaccharide**.
- They are polymers of medium to high molecular weight.
- Polysaccharides also called glycans differ from each other in the **identity of their recurring monosaccharide units**, length of their chain, type of bonds and degree of branching.
- They are further classified into
 - ☐ Homopolysaccharide and
 - ☐ heteropolysaccharide

HOMOPOLYSACCHARIDE

- **Homopolysaccharide** contain only a single monomeric specie.
- Some homopolysaccharide serves a storage form of monosaccharide that are used as fuels.
- **Starch and glycogen are examples of homopolysaccharides.**
- other homopolysaccharide (cellulose and chitin) serve as structural elements in plant.



HETEREOPOLYSACCHARIDES

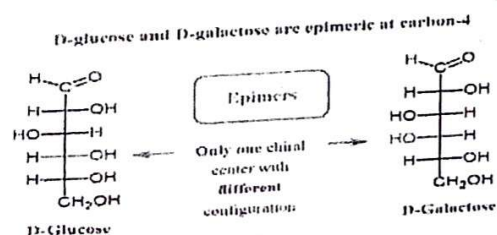
- **Hetereopolysaccharide** contain two or more different kind of monomeric specie.
- **Hetereopolysaccharide provides extracellular support for organisms of all kingdoms.** For example the rigid layer of the bacterial cell envelop (peptidoglycan) is composed in polysaccharide built from two alternating monosaccharide unit.
- In animal tissues, the extracellular space is occupied by several types of heteropolysaccharide which forms a matrix that **holds individual cells together and provide support, shape and protection for the cells, tissues and organs.**

PHYSICAL PROPERTIES OF CARBOHYDRATES

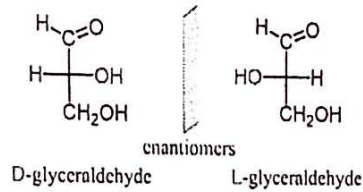
- **Mutarotation:** this is the change in specific rotation that occurs when α or β form of a carbohydrate is converted to an equilibrium mixture of two .
- Mutarotation is a process where a sugar molecule can change its structure between different forms, particularly in aqueous solutions. This phenomenon is commonly observed in carbohydrates like glucose.

• EPIMERIZATION:

- epimers are sugar molecules that differ in configuration at only one of the several chiral centers. Example of this is glucose and galactose.



- **ANOMERS:** The term anomer refers to isomers that differ in configuration at **carbon 1 (C1)** i.e anomers of glucose are isomers of glucose that differ in configuration to glucose at carbon 1.
- **CHIRALITY:** a chiral compound is a molecule that contains four different constituents attached to it and it rotates the plane polarized light.



- **Optical isomerism:** it is exhibited by compounds containing asymmetric **carbon atom**.
- Monosaccharide which causes rotation of plane polarized light to the right are called **dextrorotatory** and are designated **D or (+)**.
- Those which rotate the plane polarized light to the left are termed **laevorotatory** and are **L or (-)**.
- the two forms of glucose **D and L** are non superimposable images of each other and are called **enantiomers**.

CHEMICAL PROPERTIES OF CARBOHYDRATES

☐ Reducing property:

- Sugars are classified as either reducing or non reducing depending upon the presence of potentially **free aldehyde or ketone group**.
- The reducing property is mainly due to the ability of the sugars to reduce metal ion such as copper or silver under **alkaline condition**.
- This reducing property is the basis of **Fehling's and benedict's** test where cupric ion in copper sulphate is reduced red **cuprous oxide**.

☐ **Reaction with acids:**

➤ **Molisch's test** is a general test for carbohydrates. In this test, carbohydrates when reacted with conc. H_2SO_4 get dehydrated to form furfural and its derivatives.

☐ **Oxidation** : when aldoses are oxidized under proper condition with different type of oxidizing agent, three types of acids are produced namely; aldonic acid, uronic acid and aldaric acid.

➤ **Aldonic acid**: oxidation of an aldose with bromine water at neutral pH converts the **aldehyde group to carboxyl group**. Ketoses are not readily oxidized by bromine water.

➤ **Uronic acid**: when aldoses are oxidized with **enzymes, uronic acids are formed**. In this reaction only the primary alcohol group is oxidized to carboxyl group whereas the aldehyde group remain unchanged.

➤ Uronic acids are constituents of peptic polysaccharide.

➤ **Aldaric acid**: when aldoses are oxidized with **nitric acid, aldaric acids are formed**. Both aldehyde and primary alcohol groups are oxidized to **carboxyl group**.

➤ Glucose on oxidation with nitric acid produces **glucaric acid**. Ketose are split by the action of nitric acid to form a mixture of acids having fewer carbon atoms. **Fructose on oxidation gives a mixture of glycolic acid and tartaric acid**

• **Reaction with Alkali:**

➤ With dilute and non standing, glucose undergoes **Lobry de Bruyn-van Ekeinstein**.

➤ Glucose is partly converted to fructose and mannose and hence all the three sugars will exist at equilibrium.

➤ The same transformation with fructose or mannose.

Protein of Proteoglycans.

-glycosaminoglycan can account for up to 95% of the mass of proteoglycans.

-proteoglycans are highly hydrated and occupy large volume because their glycosaminoglycan component contains polar & ionic groups. These feature confers elasticity and resistance to compression. Important properties of connective tissues.

eg, the flexibility of cartilage allows it to absorb shock, some of the water can be pressed out when cartilage is compressed, but relief from pressure allows it to rehydrate.

Peptidoglycan

These are polysaccharides linked to small peptides. The cell walls of many bacteria contains special class of peptidoglycan with a heteroglycan component attached to a four or five residue peptide. The heteroglycan component is composed of alternating residue of GlcNAc and N-acetylmuramic acid MurNAc joined by $\beta(1-4)$ linkages.

MurNAc is a nine carbon sugar found only in bacteria. The polysaccharide moiety of peptidoglycan resembles chitin.

The antibacterial action of lysozyme results from its ability to catalyze the hydrolysis of polysaccharide chains of peptidoglycan.

The peptide component of peptidoglycan varies among bacteria.

Glycoconjugates

These consist of Polysaccharides linked or conjugated with proteins or peptides. In most cases the Polysaccharides are composed of several monosaccharide units. (e) starch, glycogen, cellulose & chitin.

(1) Proteoglycans

These are complexes of proteins and a class of Polysaccharides called glycosaminoglycans. These glycoconjugates occur predominantly in the extracellular matrix of multicellular organisms.

Glycosaminoglycans are unbranched heteroglycans of repeating disaccharide units.

As the name glycosaminoglycans indicates, one component of the disaccharide is an amino sugar either D-galactosamine (GalN) or D-glucosamine (GlcN). The amino group of the amino sugar can be acetylated, forming N-Acetyl galactosamine (GalNAc) or N-Acetyl glucose amine GlcNAc.

Several types of glycosaminoglycans have been isolated and characterized. Each type has its own ^{sugar} composition, tissue distribution, linkage and function and each is attached to a characteristic protein. Hyaluronic acid is an example of glycosaminoglycans. It is found fluid of joints where it forms a viscous solution that is an excellent lubricant. It is also a major component of cartilage.

Almost 100 glycosaminoglycan can be attached to the